Institute of Mathematics, Warsaw Technical University, Warsaw, Poland
and
Institute of Electrotechnics, Politechnika Swietokrzyska, Kielce, Poland

Some problems of the learning neuronlike system for the control of robots

Ryszard Gawronski and Bohdan Macukow

1. Introduction

On the bases of many general data concerning motor control system in higher animals and man, many authors propose different structures for voluntary control system.

In any case it is evident that such a structure may be divided in three or four levels. The highest level is a decision level which generates some rather simple signals triggering a set of processes which in the lowest level controls the appropriate muscle contractions that is voluntary movement.

It is evident that between the above mentioned levels there exist some systems (structures) which take into account the real situation, the body position and appropriate accelerations. The most important level generates a set of signals which controls alfa and gamma loops for every controlled muscle.

In spite of many investigations and models proposed we know very few on the intermediate levels of muscles control system. We try to investigate a model of a system which shows the possibility of such a hierarchical control, where the intermediate stage is a neuron-like adaptive net.

Besides it would be very interesting to have a learning system for an artificial hand of robot which can learn to perform some stereotypic movements.

In the present paper we propose a system with only three levels. On the first level a simple digital set of signals is elaborated which controls a neuron-like net for muscle control system. The net forms a second level and generates a set of signals for direct object (muscle system) control. The desired stereotypic movement is obtained after a learning procedure. In the paper (4) proof of the convergence of the learning procedure is given and some results of the modelling of the system are presented. As a result of some special algorithms based on neurophysiological ideas, an amazing fast convergence of the learning procedure was obtained.

2. Description of the System

The general structure of the system under consideration is presented on Fig. 1. Generally unknown and nonlinear object has "u" inputs (vector Y) and "1" outputs (vector Z) and satisfies the general assumption of controllability. We shall assume them

$$y^i \in \langle 0,1 \rangle \quad \text{and} \quad z^i \in \langle 0,1 \rangle$$

for every "i". The object is described by a set (usually nonlinear) equations

$$\Phi\,(Y,\ Z) = 0 \qquad /1/$$

which has one stable solution. Therefore there exists a unique but not known operator F

$$Z = F(Y) \qquad /2/$$

as a solution of the equation /1/ which is continuous and limited.

Some standard (stereotypic) output signals Z_s are given and for the measure of the error we assume

$$\| Z - Z_s \| = \sum_{i=1} | z^i - z_s^i | . \qquad /3/$$

The general task of the learning system is to generate in a number of steps (possibily minimal) such values Y_s for every "s" as to get

$$\| z - z_s \| < \delta . \qquad /4/$$

The input signals for the object are generated in the adaptive net which is a set of neuronlike elements arranged in two layers with controlled connection weights W_t^i . For the stationary state we shall assume that the net is composed of nonlinear summators described by relation

$$U = \Phi\left(\sum_{i=1} W_i \xi_i \right) \qquad /5/$$

where

ξ_i - the signal applied to the input "i" of the element,

Φ - nonlinear operator, for example described by a broken line characteristic with threshold and saturation.

The weight parameters depend on the sum of input signals V_s controlling the values of the weight in all "s" steps of the learning procedure

$$W_i = \psi\left(\sum_{s=1}^{n} V_s \right) \qquad /6/$$

The adaptive net has two kinds of inputs:

1. Binary signals $X = \{ x_1, x_2, x_3, \ldots, x_w \}$ where $x_i \in \{0, 1\}$, which are generated in a special generator by means of an assorting procedure for choice of optimal input vector (4).

2. Weight control signals which are generated in the block of automatic weight control fitted by a comparator.

In general

$$V_t^i(n) - K_t^{x} \varrho(n)(Z_n^i - Z_s^i) \qquad /7/$$

where

t - number of the inputs for the appropriate cross connections in the net for the channel "i"

k_x - constant coefficient which characterizes the mutual influences in the net,

$\varrho(n)$ - a nonincreasing function of a step number, satisfying the condition: for every $C \leq C_o$ there exist such N that for $n > N$, $\varrho(n) < C_o$. /8/

The appropriate weights of the adaptive net are changed according to the relation

$$W_t^i(n) = W_{ot}^i + \sum_{s=1}^{n-1} V_t^i(s) . \qquad /9/$$

3. <u>The description of the learning algorithm</u>

The learning algorithm for any defined stereotypic output Z_s is composed in two stages. In the first stage the generator of the input signal X determines an optimal set of input signals X_s. After many investigations of different algorithms it appeared that the appropriate method of assorting of the binary inputs X_s^i may shorten ten times (or even more) the learning procedure. In the second stage the error

$$Z_n^i - Z_s^i = \varepsilon_n^i \qquad /10/$$

signals for every channel "i" and for every learning step "n" are used for the generation of signals $V_t^i(n)$ which control the weights W_t^i according to the rule /9/. The procedure of assorting of X may be also divided in two substeps and the procedure is based on an idea of simplified identification of the object.

The algorithm of the changing of the weights in the net is divided in four substages. In every substage another group of connections is changed accordingly to the appropriate error ε_n^i.

In the paper (4) the learning algorithm is described in detail and the proof of theorem is showed also.

Theorem. When the learning algorithm satisfies the following assumptions:

1. The object is described by an unknown operator satisfying the condition of controllability,
2. The adaptive net satisfies the relations /5/, /7/, /8/, /9/ and the operator Φ in the relation /5/ is a motonic function with threshold and saturation.
3. The signals $V_t^i(n)$ controlling the weights of the net satisfy the equation /7/,
4. The input vector X is an optimal vector assorting to the special procedure (described in (4))

- then starting from the $n > N$ the learning procedure is convergent and the output signal in every channel satisfies the relation

$$\lim_{n \to \infty} Z_n^i = Z_s^i \qquad \text{for } i = 1,2,3,\dots,1$$

and for the whole system the relation

$$\|Z_{n+1} - Z_s\| < \alpha \|Z_n - Z_s\| \quad \text{for } \alpha < 1 \qquad /11/$$

is valid.

4. Results and Discussion

The learning algorithm was programmed on digital computer CDC 3170 for many different stereotypes Z_s. The modelling was made for ten different threshold characteristics of the net elements and for various objects. The asymmetrical object was also investigated. The obtained results show that:

(i) The introduction of the assorting procedure for the input signals has the essential influence on the speed of learning. The number of cycles was approximately ten times smaller than in the case of arbitrarily assumed X.

(ii) Threshold values have an important influence on the speed of learning. The threshold value ought to be approximately equal to the threshold in the object.

(iii) To enable the adaptation of the system to the generation of the set different outputs Z it is necessary to introduce the special procedure which minimize the number of changed weights during the individual stereotypic signal. This rule gives the possibility to get more different control signals Y corresponding to the needed stereotypes Z_s .

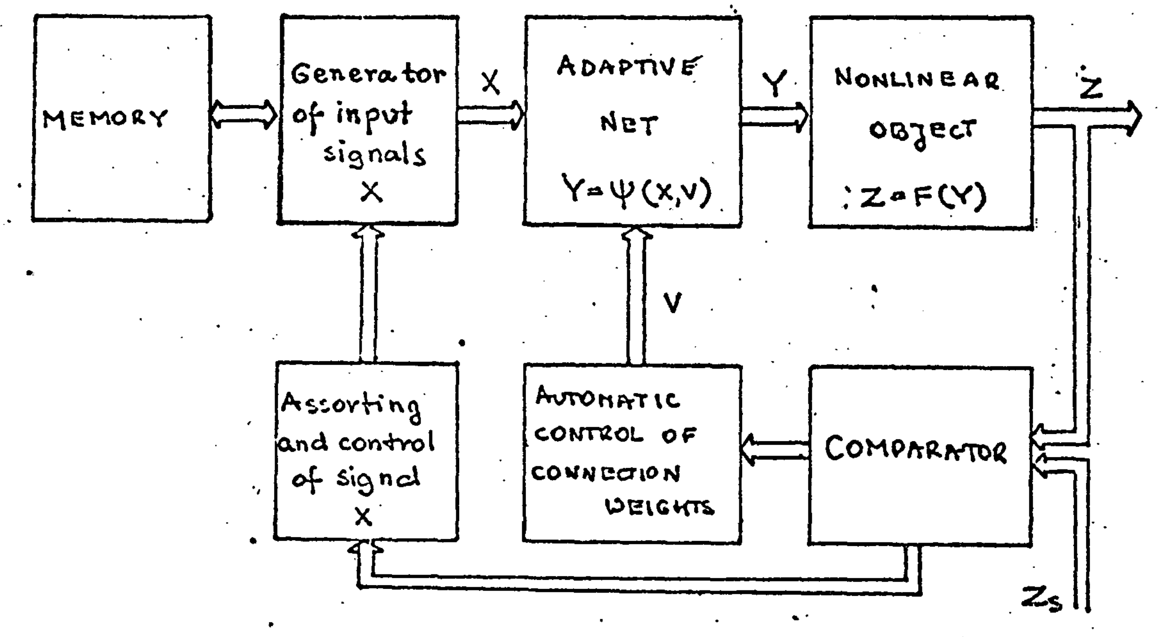

Fig. 1

Block diagram of the learning system

References

(1) "Learning Systems and Intelligent Robots", ed. K.S. Fu and J.T. Tou.Plenum Press, N.Y. 1974.

(2) Fukushima, K.: Cognition. A Self-organizing Multilayered Neural Network, Biol. Cyb. v. 20, 3/4, 1975.

(3) Andersson, J.A.: A Simple Neural Network Generating an Interactive Memory, Math.Biosci v. 14, 3/4, P. 197-220, 1972.

(4) Macukow, B., Gawronski, R.: The Learning Algorithm Using an Adaptive Net to Control the Unknown Object, Arch. Autom. Telemech. v. 21, 4, 1976.

(5) Gawronski, R., Macukow, B.: Learning System for Optimal Movement Control with Minimum Error Criterium, Mat. II CISM-IFToMM Symp. "On Theory and Practice of Robots and Manipulators", Warsaw, 1976, ~~Eselvier-PWN.~~